

CHAPTER 5

ENGINEERING SURVEYS



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CHAPTER 5 | ENGINEERING SURVEYS

5.1 Introduction

Engineering surveys provide the base mapping of existing physical features for designers on Montana Department of Transportation (MDT) projects. These surveys show planimetric features and define the 3D shape of the existing ground. Point features are represented by symbols, and line features are represented by varying types and widths. The 3D shape of the existing ground typically is defined by a triangulated irregular network (TIN), sometimes referred to as a digital terrain model (DTM).

5.2 Survey Scoping Meeting

For internal MDT projects, the survey request form will define project needs. For consultant projects, needs should be confirmed during the survey scoping meeting. The goals of the survey request form and survey scoping meeting include:

- Confirming the extents of mapping where complete topography is expected to be provided.
- Identifying any areas within mapping extents not expected to include full topography.
- Confirming whether utilities are required as part of the survey.
- Delineating what will be mapped by a traditional ground survey and what, if anything, will be mapped by remote sensing methods including terrestrial lidar, mobile lidar, or airborne photography and/or lidar ([Chapter 7: Remote Sensing](#)).

5.3 Project Equipment Selection

Engineering surveys have specific equipment needs. Project equipment selection should be tailored to meet the project's design needs. Additional information on equipment can be found in [Chapter 3: Equipment](#).

5.3.1 Total Station and GNSS Surveys

Total station engineering surveys should be used for features benefitting from higher local relative accuracy, such as:

- Bridge components.
- Hard surface features (sidewalk, curb and gutter, pavement, etc.).

High-multipath environments are also well suited for a total station. These environments include:

- Treed areas.
- Canyons or steep topography.
- Vertical structures (buildings, tanks, or silos).

Engineering surveys must use approved project control or establish secondary control in conformance with [Chapter 4: Control Surveys](#).

- Underneath bridges.



Figure 5-1: High-multipath environments are well suited for using total stations

Global navigation satellite system (GNSS) engineering surveys are appropriate for:

- Soft surface mapping.
- Relatively low-multipath environments.

Areas where GNSS is proposed for hard surfaces should be identified during scoping or on survey request forms.



Figure 5-2: Example of a low-multipath environment

5.3.2 Alternative Methods

Alternative methods to a traditional ground survey may be considered when there is a clear advantage to using them. Alternative methods include terrestrial laser scanners, mobile lidar, echosounders, unmanned aerial vehicles (UAVs), and future emerging technologies. MDT is flexible in using alternative methods, but the resulting data needs to meet department standards and project objectives. Non-typical equipment may benefit a variety of situations.

Terrestrial laser scanners may be appropriate for engineering surveys of:

- Roadways and intersections with high-speed or high-frequency traffic.
- Bridge structures and substructures.
- Miscellaneous complex features benefitting from a high level of detail such as manholes and vaults.

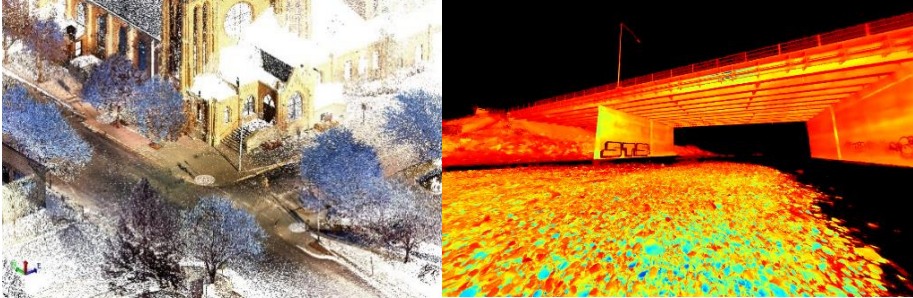


Figure 5-3: Scanner-derived point clouds of an intersection (L) and a bridge (R)

Mobile lidar may be considered for long corridors benefitting from high-density information or for areas that cannot otherwise be occupied safely by personnel or equipment.

Engineering surveys involving point clouds should consider the needs and capabilities of the end user(s) of the survey and if simpler methods can provide the necessary information. Processing time may be intensive when extracting features from lidar point clouds. See [Chapter 7: Remote Sensing](#) for standards.

Echosounders allow surveyors to gather bathymetric survey data unattainable through traditional methods like a wading survey with GNSS or a total station. Single-beam echosounders can be paired with either GNSS or a total station to determine depths of rivers or lakes. Multibeam or side-scan echosounders may be useful in a situation requiring a detailed point cloud of the river or lake floor (e.g., for detailed bridge scour assessments). [Chapter 5: Engineering Surveys](#) provides more information.

UAV sensors are highly variable in cost and performance. The suitability of a UAV for any project depends on the sensor collecting data. Photogrammetry-type UAVs excel at capturing current high-resolution orthoimagery but may be less reliable than other mapping options for developing a surface model in areas with significant vegetation. Depending on the sensor deployed, lidar-type UAVs can be useful for mapping large areas with vegetated cover. See [Chapter 7: Remote Sensing](#) for standards.

During scoping, all alternative methods should provide expected accuracies and identify methods for controlling and checking the dataset.

5.4 Engineering Survey General Standards

The following standards relate to conducting engineering surveys for MDT use.

5.4.1 Control

Engineering surveys must use approved project control or establish secondary control in conformance with the procedures in [Chapter 4: Control Surveys](#).

Check shots should be performed during every survey to verify instrumentation is set up properly. Total station setups should perform a check to the backsight

control point and a check to a foresight control point. Errors may indicate further investigation into prism constants and target heights or disturbed control points. GNSS setups similarly should check into a control point to verify antennae heights and that the GNSS integer ambiguity has been solved correctly. Errors may indicate a poor GNSS environment or set-up errors.

Control positions tend to deteriorate with time from forces like freeze/thaw and plate tectonics. Analyzing control checks for reasonable deterioration requires professional judgment informed by specific project requirements and general professional experience.

Secondary control may be added when existing project control cannot be occupied. Secondary control can be established by meaning coordinates determined by GNSS observations from two or more control points. If GNSS cannot be used to establish secondary control, a total station can be used to establish the secondary control by performing a closed traverse.

Alternatively, secondary control may be determined by performing a three-point resection. Errors in the resection and control checks should be analyzed for reasonableness using professional judgment and should conform with guidance in [Chapter 4: Control Surveys](#).

5.4.2 Feature Codes

Feature codes are descriptive text fields collected for all points that represent an abbreviated version of a given feature such as EOP for edge of pavement or BOB for bottom of bank. The feature code can be used by field and office software to determine:

- Whether the item is a point feature or linear feature.
- Whether the point will be included in the existing ground surface model.
- Whether linear features are breaklines and cannot be triangulated across in the existing ground surface model.

Table 5.1 shows a sampling of feature codes. All feature codes and a description of how they should be surveyed can be found in [MDT's Feature Code Summary](#). MDT also provides a [Feature Code Reference Sheet](#) that shows all codes and a short description in a concise format.

CATEGORY	CODE	FEATURE	POINT OR LINE	DTM OR NON DTM	BREAKLINE?	COLLECTION POINT(S)
Drainage	CULVI	End of culvert invert	Line	Non-DTM		At the end of a pipe or invert, at both the end treatment and pipe end when end treatments are present.
Misc.	CORE	Core/drill hole	Point	Non-DTM		At the center of the geotechnical boring hole.
Natural	BOB	Bottom of bank (natural slope)	Line	DTM	Yes	Along the bottom of the bank.
Natural	GRND	Ground shot or mass point	Point	DTM		On the existing surface of a random ground shot or at the center of the mass.

Table 5.1: Sampling of Feature Codes

A point can use multiple feature codes; for example, SW CONC could be used where a sidewalk intersects with another concrete slab. Multiple lines of features with the same name can be run by adding a numerical suffix to a feature code; for example, EOP01, EOP02, and EOP03 are used in Figure 5-4 to represent the multiple edge of pavement points.

Line control codes can be used following feature codes to start and stop lines and draw curves. MDT uses the following control codes:

- BL – Begin line.
- EL – End line.
- SSC – Start smooth curve.
- ESC – End smooth curve.
- CL – Close line.

Figure 5-4 shows the application of control codes BL and EL to begin and end lines.

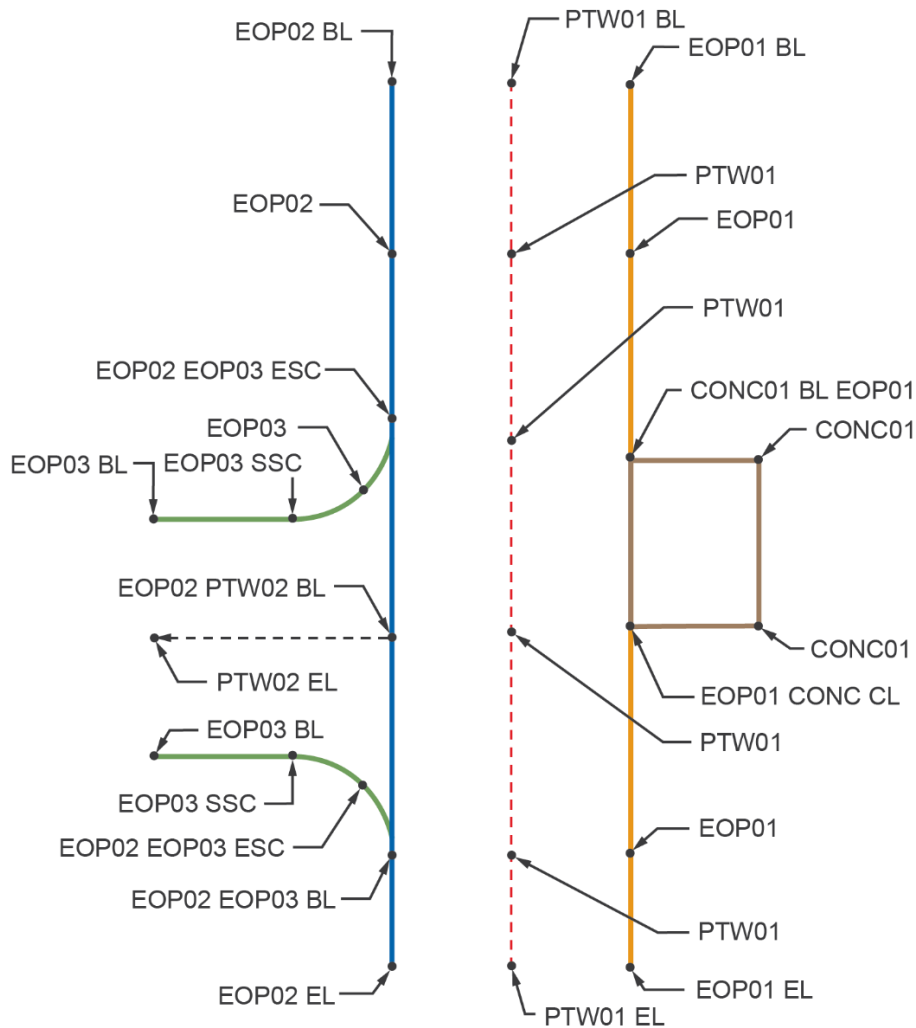


Figure 5-4: Sample feature coding showing line control codes and double coding

5.4.3 Point Attributes

Depending on the feature code entered, a point may have one or more attribute fields providing supplemental data about a feature. For example, collection of the feature code ABUT at a bridge abutment will give the user an option to enter an attribute to define the width of the abutment. The feature code TREE will give the user options to enter species, height, and trunk diameter. When collecting points with attributes, only one feature should be surveyed for each point. See MDT's [Feature Code Summary](#) for attributes available for each feature and Section 5.5.4.1.2 for detailed information on culvert attributes.

USER TIP:
Careful use of the active map screen while mapping can prevent drafting errors, including crossing breaklines.

5.4.4 Point Numbering and Spacing

Engineering surveys should use unique points numbered 50,000 and up. Point spacing generally is dictated by terrain and feature complexity. Points should be located no farther than 25-ft. apart and at a sufficient density to define features horizontally and vertically.

5.4.5 Breaklines and Surfaces

Breaklines are 3D lines that add definition to an existing ground surface by controlling the behavior of the TIN model or DTM. A TIN will not allow a triangle edge to cross a breakline. Figure 5-5 shows an example of a crossing breakline.

Some DTM features (e.g., GRND or ground shot) are only points with a surface elevation at the point location. Breaklines force the surface model to interpolate between two or more DTM points.

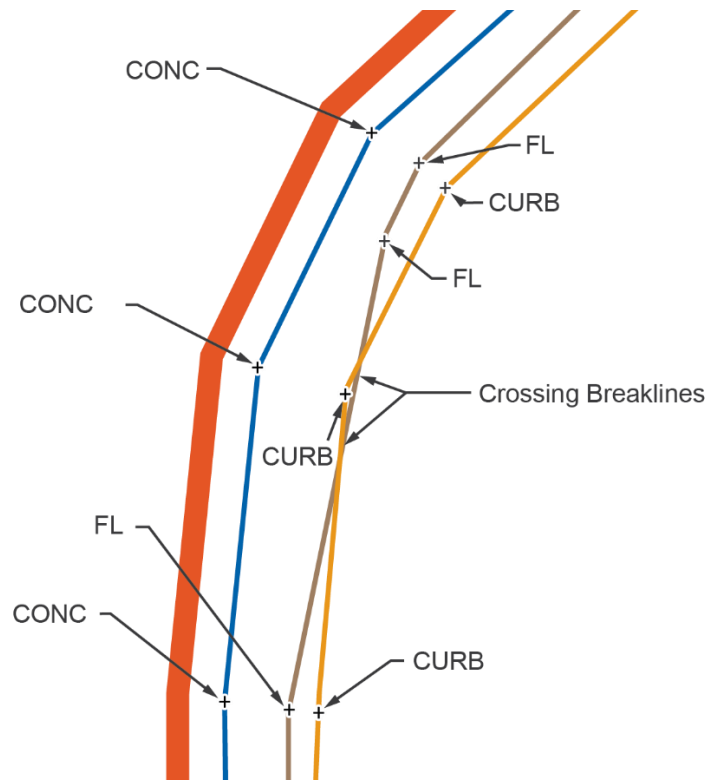


Figure 5-5: Crossing breaklines

5.4.6 Curvilinear Features

Curved features should either be surveyed into short chord segments or as smooth curves using line control codes.

5.4.7 GNSS Observations

In engineering surveys, GNSS observations should be three or more epochs in length. Continuous real-time kinematic methods are generally only allowed for bathymetric surveys but may be considered for projects during the survey scoping meeting if there is a project for which it is well suited (e.g., a project with an urgent timeline and relatively consistent flat topography).

5.5 Hydraulic Surveys

Survey personnel perform hydraulic surveys as a specialized subpart of engineering surveys. Hydraulic surveys at MDT comprise data for both hydraulics – the study of fluids through engineered systems – and hydrology – the study of the behavior of water in its environment. These surveys collect data for designers to understand how the hydraulics and hydrology of existing systems may be impacted or altered during project design engineering. Each project has unique needs and may require coordination between survey, hydraulic design, transportation design, structural design, and aerial mapping providers. For internal MDT projects, survey requests are included in the project Location Hydraulic Study Report (LHSR). For consultant projects, needs should be confirmed internally with the consultant’s hydraulic design team and externally during the survey scoping meeting.

5.5.1 Survey Scoping Meeting and Hydraulics

The hydraulic survey request forms or survey scoping meeting should identify:

- Where ground survey is expected to be needed for hydraulics.
- What type(s) of hydraulic ground surveys are needed (e.g., cross sections, structure survey, channel topography).
- Where remote sensing is expected to be used for hydraulics (e.g., where aerial mapping may be used to model cross-sectional topography).
- Where heavy vegetation and/or trees are expected to render aerial mapping (and usually GNSS receivers) less effective.

Existing as-builts and other types of annotated maps may be helpful for documenting hydraulic survey scope needs and can be distributed to field personnel in advance of the survey.

On complicated internal projects, MDT Hydraulics provides survey personnel with a computer aided design drawing (CADD) file showing desired cross section locations and areas to be mapped to develop a TIN (see Section 5.5.3).

5.5.2 Local Information

Field personnel should document and report to hydraulic design any interactions with local sources that could provide useful information pertaining to hydraulics. This includes but is not limited to information related to:

- High water events.
- Overtopping locations.
- Existing deficiencies.
- Irrigation operation and performance.

5.5.3 Topographic Data

Hydraulic ground surveys are developed into the project DIMAP. The DIMAP is an electronic drawing prepared in MDT's current drafting design software that comprises exclusively hydraulic survey data, including points, linear features, and, where required, a surface terrain model in the form of a TIN. The purpose of a DIMAP TIN is to fill in the locations where ground surface data are needed for hydraulics.

Ground surveys of topography for hydraulics generally should conform with Engineering Survey General Standards. Points of emphasis include:

- Hydraulic survey points should be observed from primary or secondary project control points.
- Hydraulic survey areas are frequently treed or obscured overhead by bridge decks. GNSS should not be used in high-multipath environments.
- Topography should represent significant horizontal and vertical changes in features.
- Survey points for a contiguous survey area along a cross section or along a profile should have a maximum point spacing of 25-ft. or as defined by the hydraulic engineer.

Hydraulic topographic surveys should be produced to meet the American Society of Photogrammetry and Remote Sensing (ASPRS) vertical positional accuracy class of 15 cm, which, for reference, is the closest equivalent mapping class in the current standards to the former National Map Accuracy Standard's 1-ft. contours. See the current [ASPRS Positional Accuracy Standards for Geospatial Data](#) and [Chapter 7: Remote Sensing](#) for additional information.

Photographs can be especially useful for documenting conditions of hydraulic structures like culverts and bridges. Photo files should be indexed with a corresponding point number in the survey. The point number should be in delivered photo file names and should represent the feature being surveyed.

5.5.4 Culvert Surveys

Culverts convey water under roadways, approaches, and other transportation infrastructure and play a critical role in managing stormwater runoff and flood prevention. Field personnel are responsible for collecting survey data points at culverts and for collecting culvert attribute information.

5.5.4.1 Standard Culvert Information

Data points are collected by GNSS or total station observations. Attributes are observed in the field and related to individual points using data collection software.

5.5.4.1.1 Common Data Points

Field personnel should survey all culverts identified by hydraulic design in the hydraulic survey request form. The common data points associated with this feature are thalweg or flow line (feature code: FL), centerline of roadway (PTW), top of culvert/pipe (CULVT), and end of pipe/culvert invert (CULVI). Flow line observations should terminate/begin at the pipe end or pipe end treatment; they should not connect through the culvert. In silt- or sediment-filled pipes, flow line should be observed where the water truly flows (i.e., at the lowest point of the top of sediment or silt through the pipe).

Field personnel should dig out culvert inverts covered with sediment, debris, snow, or ice to observe the true culvert invert. See the MDT Feature Code Summary documentation for the most up to date guidance on feature coding for culverts.

5.5.4.1.2 Culvert Attributes

Culvert attributes provide end users with data to complete design functions such as hydraulic modeling to evaluate when an existing or designed culvert would be expected to flood.

Pipe Size

The pipe size attribute is expressed in inches.

Circular pipe size refers to the inner diameter of a pipe. Typical circular pipe sizes include each 3-in. interval between 12-in. and 24-in. and each 6-in. interval between 24-in. and 84-in.

Non-circular pipe sizes refer to an equivalent inner diameter for arch pipes and structural steel plated pipes (SSPPs). Arch pipes are typically described in terms of span (cross-sectional width) and rise (cross-sectional height).

The relationship between span, rise, and equivalent diameters can change depending on corrugation type. For a complete list of potential sizes encountered and their equivalent diameters, see the [MDT Hydraulics Manual: Chapter 11](#).

Pipe size should conform with the survey data points collected for CULVI and CULVT, accounting for wall thickness. For example, a circular corrugated metal pipe (CMP) with a diameter of 18-in. should have an elevation difference close to 1.5-ft. between CULVI and CULVT observations because corrugated metal pipes typically have a thin pipe wall. A circular reinforced concrete pipe (RCP) with a diameter of 24-in. and a pipe wall thickness of 3-in. should have an elevation difference close to 2-ft., 3-in., or 2.25-ft. Be alert for changes in pipe wall thickness as pipe sizes increase. Verify the surveyed pipe size conforms with typical type sizes and is not due to a damaged culvert end.

Pipe Material

Pipe materials are commonly referred to by acronyms like RCP and CMP. See Table 5.2 for a list of common materials and their acronyms. For a complete list of pipe materials, see Table 11.4-1 in the *MDT Hydraulics Manual*.

Care should be taken to properly differentiate between corrugated metal pipes and structural steel-plated pipes. Corrugated metal pipes are fabricated in sections of whole pipe, whereas plated pipes are built from corrugated plate sections that are bolted together to form the desired shape. See Table 5.1 at the end of the chapter for photo samples of pipe materials.

USER TIP:
If a culvert is filled with sediment, survey the flow line at the sediment elevation and dig out the culvert to survey the culvert's invert.

ACRONYM	PIPE MATERIAL
CMP	Corrugated Metal Pipe, circular shape, commonly found
CMPA	Corrugated Metal Pipe, Arch shape
HDPE	High-Density Polyethylene, also referred to as corrugated plastic pipe
PVC	Polyvinyl Chloride – uncommon in hydraulics but occasionally encountered
RCB Single	Reinforced Concrete Box, single cell
RCB Double	Reinforced Concrete Box, double cell
RCP	Reinforced Concrete Pipe, circular shape, commonly found
RCPA	Reinforced Concrete Pipe, Arch shape
SSPP	Structural Steel Plated Pipe, circular shape
SSPPA	Structural Steel Plated Pipe, Arch shape
OTHER	Miscellaneous pipe materials otherwise not listed

Table 5.2: Pipe Materials and Their Acronyms

Pipe Coating

A pipe coating is a continuous flexible layer added to a pipe to improve longevity. Options for pipe coating attributes are:

- Polymeric – Bituminous or non-asphalt polymeric coatings.
- Metallic – Galvanized (zinc or iron) or aluminum.
- None.

Culvert End Treatment Type

Culvert end treatments protect culverts and provide transitions to surrounding terrain. Options for culvert end types are:

- FETS – Flared end terminal section.
- Square – A square end treatment.
- RACET – Road approach culvert end treatments look like a partial culvert extension with horizontal metal bars or pipes placed perpendicularly along the top of the partial culvert extension.
- Beveled.
- RCB Sloped – RCB with a sloping end section.
- RCB Flared – RCB with wingwalls that are level or sloping.

See Table 5.3 for photo examples of end treatments.

Edge Protection

Edge protection refers to material placed at the pipe edge generally to prevent erosion and increase longevity. Options for this field include:

- Concrete.
- Riprap.

- Other.

If riprap or concrete edge protection is present, the perimeter extent of the protection should be surveyed as a linear feature.

End Damage

End damage is a yes/no field determined by assessing whether the pipe has been damaged. Additional information describing the damage (e.g., SQUISHED) may be added to the comment attribute field.

Amount Embedded

Amount embedded refers to the amount of material present inside the pipe. Assess embeddedness on a scale of 0% full to 100% full in 25% increments. A surveyed point (typically coded FL) should be observed at the top of the embedment.

Usage Type

Usage type is an attribute assessed in the field based on the context of a culvert's environment. Usage type attribute options are:

- Drainage – Culverts used to convey drainage waters.
- Irrigation – Culverts used to convey irrigation waters.
- Stock pass – Culverts used to move stock across transportation corridors.
- Drainage stock pass – Culverts used for both stock and drainage, often located at a low spot in the road profile.
- Other – Wildlife crossings, pipe sleeves, etc.

Comment Field

Comments are a text field used for pertinent data, including:

- Descriptive text like SQUISHED can help explain discrepancies between pipe diameters and culvert survey shots.
- Pipe corrugations or pipe gages may be helpful if they can be ascertained by field personnel. See [MDT Hydraulics Manual](#) for additional information on corrugations and gages.

Culvert Photos

Field personnel should take photos at each culvert and index them by point number or as-built stationing. A well-composed photo can help office personnel confirm attributes were collected and entered correctly. Each culvert should have photos taken of the following features:

- Inlet and outlet of culverts.
- Upstream and downstream views of channel leading to and from culvert.
- Locations of scour or erosion near the culverts or in road ditches.
- Overtopping location (roadway, ditch bank, or basin divide).

Photos of culverts should feature environmental context of the culvert ends but be close enough to identify pipe type and approximate diameter. Review photos in the field to confirm they are not poorly lit and/or poorly focused.

5.5.4.2 Thalweg

The thalweg, is the lowest elevation of a watercourse. This term is used to determine the boundary between two deeds separated by a watercourse. Surveyed thalweg points are recorded as thalweg and are not the same as flowline (FL/FLU) used with a culvert topographic mapping..

5.5.4.3 Cross Sections

Hydraulic cross sections are a linear series of points that sample topography, typically perpendicular to streamflow or flood flows. Cross sections should be surveyed for all culverts 36-in. or greater in diameter and for any additional culverts identified by hydraulic design.

Channel cross sections should, at minimum, include the following:

- Survey one channel cross section perpendicular to flow upstream and one downstream. Channel cross sections typically include significant grade breaks (GB), tops of bank (TOB), bottoms of bank (BOB), thalweg (FL), and edge of water if present (EDGEWAT) at water surface elevation. Survey edge of vegetation where seasonally disturbed by streamflow if discernible (MISCL EDGEVEG or MISC P EDGEVEG). Include cross sections of nearby ditches or drainages that run parallel to the channel for your culvert.
 - The downstream cross section should be placed at the most constricted nearby portion of the watercourse.
 - Areas with scour downstream should have a cross section at the scour location and at the most constricted nearby portion of the watercourse.
- To prevent cross section feature codes from crossing on the data collector map or during processing, use begin line or end line commands.

5.5.4.4 Existing Roadway Centerline

Provide a roadway centerline profile (cross section) to delineate the potential overtopping location(s). Provide shots at 25-ft. (10m) intervals along the existing roadway centerline a minimum of 400 ft. (120m) left and right of the pipe, unless otherwise noted in the hydraulic survey request. Survey of the roadway centerline is necessary to find the overtopping location such as a vertical sag located within the floodplain. Include a shot at each end of any solid barrier rail if present.

5.5.4.5 Upstream and Downstream Structures

Survey the footprint and floor of structures upstream and downstream that could be affected by culvert-related flooding. Structures may include residences, outbuildings, hay barns, or similar improvements. These structures are typically identified during scoping by hydraulic design personnel, but field personnel

should also be observant of structures near culverts that could be damaged by floodwaters if the culvert were to fail to convey water.

5.5.4.6 Springs

Survey freshwater springs when present and contributing to a culvert.

5.5.4.7 Water Surface Elevations and High-Water Marks

Survey the water surface elevation if water is flowing through a culvert at the time of the survey. Survey both sides (EDGEWAT) at the same interval as thalweg observations.

Survey high-water marks (HIWATER) when present. These may include stains on edge protection, rust lines on the culvert, or debris lines at the culvert inlet. Take a photo that clearly identifies where the high-water mark was surveyed.

5.5.4.8 Scour and Erosion

Survey evidence of erosion when present near culverts. This may include scour holes, erosion of fill, and channel headcutting. Scour holes form where turbulent water erodes the streambed and forms a depression. Erosion of fill around pipe ends may be identified by irregular and uneven surfaces with a lack of soil cover. Channel headcutting can be identified by notable change in the thalweg elevation that deviates from what would appear to be the normal profile of the channel.

Erosion can threaten the longevity and effectiveness of culverts, making it a key concern for the hydraulic design team. Use photos and point feature codes to document erosive conditions.

5.5.4.9 Major Detailed Culvert Surveys

Hydraulic design may identify large culverts that will require a higher-level detailed survey, similar to what is required for bridges.

In addition to standard culvert information, detailed culvert surveys also may require survey of:

- Detailed topography near the structure consistent with Section 5.5.3.
- A bank-to-bank survey of the channel 500 ft. upstream and 1,500 ft. downstream, including thalweg, top of bank, edge of vegetation, edge of water, bottom of bank, and grade breaks.
- Cross sections perpendicular to flood flow at locations identified by hydraulic design. Cross sections should include ground (feature code: GRND), top of bank (TOB), bottom of bank (BOB), thalweg (FL), edge of vegetation (MISCP EDGEVEG), edge of water (EDGEWAT) at water surface elevation, and grade breaks (GB). Use “begin line” or “end line” control commands to prevent linear features from forming.
- Longitudinal roadway profile consistent with Section 5.5.4.4.
- One or more cross sections over the roadway and parallel to the pipe.
- The field-assessed overtopping point. The overtopping point refers to the location at which water would spill over a given structure, often a roadway bank or basin divide. The overtopping point can be visualized by imagining the culvert being plugged or overwhelmed with water,

causing water to stack up and fill like a bathtub. At what point would water on the inlet side begin to spill over to the outlet side? The overtopping point is often – but not always – at the center of the road and above the top of the culvert. Overtopping points can be difficult to identify in the field, and collecting multiple points or profiles may be necessary.

5.5.5 Bridge Surveys

Bridge surveys are used to develop models to predict the behavior of water over a range of flow conditions. Bridge survey and detailed culvert survey requirements are similar, but bridges require additional survey and observation of specific features.

5.5.5.1 Topography

Like a detailed culvert survey, bridge surveys require collection of detailed topography near the structure consistent with Section 5.5.3. This includes the area under the bridge, which will almost always require its own total station setup. See the Secondary Control section of [Chapter 4: Control Surveys](#).

Depending on the project and its hydraulic modeling approach, the topographic area requiring survey for hydraulics may extend hundreds of feet or more away from a given structure. Shifts in a project roadway alignment or project temporary detour design can also extend hydraulic topography needs. Lidar, photogrammetry, and ground survey – or a combination of them – may be necessary to collect this data.

5.5.5.2 Bridge Details

This section provides a list of required survey items for bridge surveys. Figure 5-6 illustrates many of the required features.

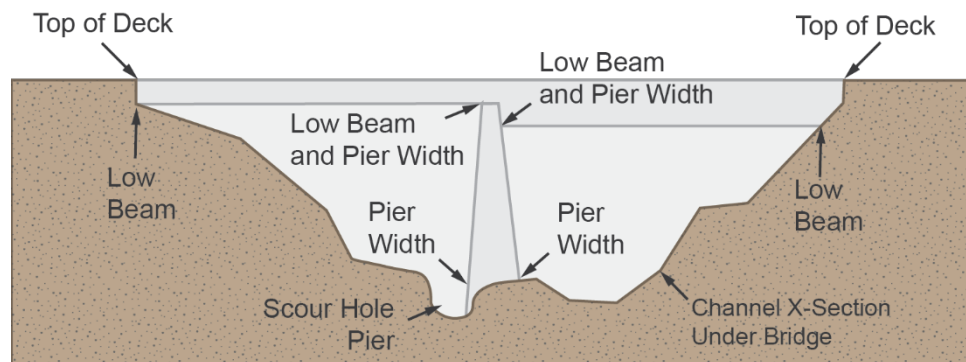


Figure 5-6: Bridge detail illustration

5.5.5.2.1 Low Beam

Low beam (feature code: LOWBEAM) refers to the lowest part of the bridge structure that can potentially impede the flow of water. The low beam is often, but

not always, the bottom of the girders that rest on top of piers and abutments at the bridge ends. Survey significant vertical changes in the low chord at each pier.

Low chord should be surveyed on both upstream and downstream bridge faces.

5.5.5.2.2 Pier Locations and Sizes

Survey pier locations and provide their dimensions, including the pier cap itself. Data collector routines can also be used to compute the center of the pier. Piers or piles that are driven at an angle (instead of vertically plumb) are referred to as battered. Collect survey data to define the batter angle of such piers. Sketches or photos, ideally with surveyed points superimposed, may be useful to help hydraulic design personnel understand how the surveyed points relate to the overall structure.

5.5.5.2.3 Left and Right Abutments

Survey the inside top edge of abutments (ABUT) and or retaining walls. Note its width as an attribute. See Figure 5-7.

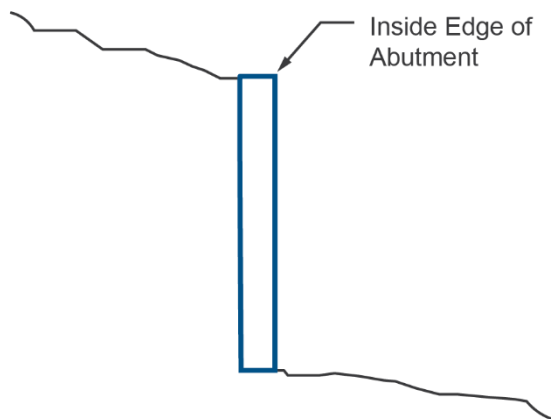


Figure 5-7: Survey of an abutment's inside edge

5.5.5.2.4 Cross Section Under Bridge

One cross section should be placed intentionally under the bridge near roadway or rail centerline. Code these points using their standard feature code descriptions like TOB, BOB, etc.

5.5.5.2.5 Bridge Deck Corners

BRCOR is a linear feature code that should represent the shape of the bridge. Collect enough points to represent irregular shapes and curvature.

5.5.5.2.6 Bridge Centerline Profile

Survey roadway profile (PTW) to the extents desired by hydraulic design. On superelevated roadways, survey the high and low side of the roadway prism using the appropriate physical feature such as edge of concrete, edge of pavement, or shoulder.

5.5.5.2.7 Nearby At-Risk Structures

Hydraulic design may identify private structures upstream and downstream of bridges that could be at risk of flooding. Survey the footprint and floor.

5.5.5.3 Channel Survey

Survey thalweg (feature code: FL), top of bank (TOB), edge of vegetation (MISP EDGEVEG), edge of water (EDGEWAT) at water surface elevation, bottom of bank (BOB), and grade breaks (GB) 500 ft. upstream and 1,500 ft. downstream of the culvert unless specified by the hydraulic engineer.

5.5.5.4 Cross Sections

Survey cross sections at the following locations:

- Locations identified by hydraulic design.
- Immediately upstream and downstream of the bridge, outside of the bridge and roadway fill slopes.
- At significant changes in drainage topography (e.g., if one side of overbank terrain changes from steep cliffs to a flat floodplain).

Include points at thalweg (FL), top of bank (TOB), edge of vegetation (MISCP EDGEVEG), edge of water (EDGEWAT) at water surface elevation, bottom of bank (BOB), and grade breaks (GB). Cross sections should be perpendicular to flood flow and should extend laterally above the maximum possible flood elevation. Cross sections where aerial mapping is not available can be 2,000 ft. or greater in length.

5.5.5.5 High-Water Marks

Survey high water marks (e.g., stains on piers or abutments, debris lines on edge protection, rust lines on culvert, or debris lines at the culvert inlet). These points can be coded HIWATER.

5.5.5.6 Scour and Erosion

Survey significant scour holes observed at bridges by collecting ground points, thalweg points, and grade breaks if discernible.

Survey channel head cutting where the thalweg profile deviates from the apparent normal slope of the channel. Collect bank-to-bank topography (TOB, BOB, FL, GRND, GB) to encompass the upstream and downstream ends of the vertical change.

5.5.5.7 Existing Riprap

Survey the perimeter of bridge riprap (feature code: RIPRAP). Riprap can be considered large rock, concrete rubble, and gabion baskets filled with rock.

5.5.5.8 Photos

Photos should be indexed by point number and/or with direction and location of each photo somehow documented. Photos should be included from the following locations:

- From bridge looking upstream and downstream.
- At all cross sections showing overbank vegetation and channel characteristics.
- Looking upstream and downstream in channel.

- Looking across floodplain from end of cross section.
- Piers (if applicable) and abutments; both upstream and downstream faces.
- Additional structures upstream or downstream of roadway bridge.
- Locations of scour or erosion visible during survey.
- Locations of high water surveyed shots.
- Unique items such as irrigation features crossing channels, head cuts, natural drops in channels, etc.
- Roadway left and right of the bridge.

5.5.6 Bathymetric Surveys and Echosounders

Channel surveys or cross section surveys for bridges or culverts may be too deep to wade and survey with a traditional GNSS pole or total station rod. A single-beam echosounder paired with a GNSS receiver or total station can be used to complete cross sections and channel surveys for most projects with areas too deep to wade.

Real time kinematic (RTK) and/or post-process kinematic (PPK) observations are acceptable for echosounder surveys. Follow the echosounder manufacturer's guidance for calibrating the echosounder, and overlap the echosounder with traditional data from GNSS or total station at multiple locations to verify echosounder is working correctly.

Alternative bathymetric remote sensing tools such as multibeam or side-scan echosounders may be deployed for projects requiring a higher level of detail at the channel floor and piers. These alternative tools and the methods to check and ensure their quality should be discussed as part of project planning and scoping, including during the survey scoping meeting. Additional deliverables may be required for these surveys and should be confirmed before conducting the field survey.

5.5.7 Irrigation Surveys

Given their importance to landowners before and after transportation projects, MDT strives to maintain or improve the function of nearby irrigation facilities and/or systems. Complete survey data facilitate an accurate assessment of existing conditions, which in turn aids the design processes that follow.

5.5.7.1 Irrigation Culverts and Bridges

Irrigation bridges and culverts generally should be surveyed consistently with drainage counterparts in Sections 5.5.4 and 5.5.5, respectively. Hydraulic design should identify areas where irrigation structures need detailed topographic surveys. Detailed topographic surveys should be completed consistent with Section 5.5.3.

Irrigation structures are frequently attached to a headwall or other transition structures; define such structures using feature codes like ABUT (top of wall or abutment) and CONC (concrete edges).

Surveys should include operating water surface upstream and downstream of the structure. Note the time and date of operating surface elevations in the feature code (e.g., EDGEWAT 06MAY23 12P).

5.5.7.2 Ditch Surveys

The following ditches should be included:

- Ditches connected to a bridge or culvert identified for survey by hydraulic design.
- All ditches within 250-ft. of the roadway.
- Any ditch running parallel with the roadway that could be disturbed by construction.

For structures identified by hydraulic design, survey the ditch 150 ft. upstream and downstream, maintaining the standard 25 ft. maximum point spacing or what was defined by the hydraulic engineer. Survey the complete ditch prism, including thalweg, top of bank, bottom of bank, grade breaks, and edges of water at water surface elevation.

Beyond these limits, hydraulic design personnel may request extended thalweg observations to determine the hydraulic profile of the channel. The extended thalweg area could be thousands of feet in length.

5.5.7.3 Cross Sections

Hydraulic design may identify cross sections to supplement ditch surveys. Cross sections should be placed at locations where the section is a good representation of the channel and where the channel shape or profile changes significantly. Cross sections should cover how the ditch bank ties into adjacent terrain, but hydraulic cross sections generally do not need to be as long as drainage cross sections.

If a road is present at the irrigation structure, survey a cross section of the road centerline profile if the road is crowned or flat. If the road is superelevated, survey both the high and low features of the roadway.

5.5.7.4 Structures

The following irrigation structures should be surveyed if they are either within the right-of-way or identified by hydraulic design as needing survey:

- Division structures.
- Check structures.
- Drop structures.
- Head gates attached to small sections of pipe.
- Slide-gates.
- Flumes.
- Pivots.
- Alfalfa valves.

- Pipe risers.
- Air vents.
- Flow Measurement Weirs.

The following information is required at irrigation structures:

- Material type – Documented in field notes or using point coding or attributes.
- Survey points to define:
 - Top of structure shape.
 - Shape of entire structure floor.
 - Wingwalls and headwalls with wall thickness noted using either point coding or attributes.
 - Ditches leading to and from the structure.
 - Water stains on structures that may identify standard operating water surface elevation.
 - Key elevations including the bottom of the structure, flowlines, headgates inverts, and weir elevations.

5.5.7.5 Water Surface Elevations and High Water Marks

Water surface elevations and high water marks for irrigation pipes and structures are typically showing constant operating water surface elevations. These are one of the most important items that can be surveyed for irrigation designs.

The most significant difference between drainage pipe/bridge crossings and irrigation crossings is the estimated water that the crossing will see. Flows at drainage crossings are estimated based on multiple drainage area characteristics, and they are typically highly variable. Flows at irrigation crossings are usually quite constant and can be estimated based on known water rights and in system controls like head gates.

Therefore, all water surface elevations and water marks on pipes, bridges, or irrigation structures need to be surveyed. These water surface elevations are critical in calibrating designs and providing adequate conveyance capacity for new irrigation pipes and structures. Water surface elevations surveyed along the ditch are also used to develop a water surface profile to help lay out a new pipe, especially if the ditch is very flat. See Figure 5-8 for examples of high water marks.



Figure 5-8: Irrigation highwater marks

5.5.7.6 Photos

Photos should be taken at all irrigation structures surveyed. See Section 5.5.4.1.2 for culvert photos required and Section 5.5.5.8 for bridge photos required. Add photos at locations where ditch characteristics change.

5.5.8 Urban Storm Drainage

Urban storm drain systems collect, convey, and manage stormwater runoff. Survey data of these systems are used to understand which areas contribute water to the system and how much water the system can handle.

5.5.8.1 Contributing Area

Contributing area refers to the catchment area within a watershed that contributes runoff to a specific point of interest like a storm drain inlet or reservoir.

Hydraulic design may identify areas requiring ground survey to analyze the contributing area. These areas could include anticipated aerial mapping voids or areas beyond project mapping (e.g., distant curblines).

5.5.8.2 Manholes, Inlets, and Pipes

At manhole or inlet structures identified by hydraulic design, perform the following:

- At curb inlets, survey the inlet rim elevation at the flow line of curb at the middle of the inlet, and note the grate size.
- Survey middle of lid or grate for manholes and all non-curb inlets. For grates, indicate the grate size.
- Determine manhole or inlet invert elevations with a measuredown, or survey the invert location directly with GNSS or a total station.
- Note size and shape of structure barrel.
- Note compass direction of pipes within the structure.
- Note pipe material, shape, and diameter within the structure.

Noted items need to be collected and transmitted to the design team. This can be accomplished with handwritten field notes or partially prefilled forms of the required items.

5.5.8.3 Other Storm Features

Hydraulic design may identify additional miscellaneous storm features requiring survey, such as slotted drains, curb openings, infiltration basins, and water treatment devices. For slotted drains, survey the extents of the drain and note the dimensions and quantity of the slotted portion(s) of the inlet. At curb openings, survey the back of curb and flow line of curb to define the opening width and height.

Infiltration basins are shallow ponds that allow surface water to enter permeable soils and pass through to the groundwater aquifer. Where present, survey the extents of the pond with enough survey data to conform with Section 5.5.3.

Water treatment devices may appear similar to inlets or manholes. These devices remove surface contaminants via filtration (e.g., media treatments) or physical processes (e.g., vortex separation unit). Collect data at water treatment devices in a similar fashion to other manholes and inlets. Take measuredowns to document the elevations of any devices. Contact hydraulic design personnel to determine if any additional survey data are needed.

5.5.8.4 Outfalls

An outfall is a structure where stormwater runoff from a storm drainage system is discharged into natural drainage. Survey the following:

- Invert and top of outfall pipe.
- Channel downstream of outfall until it reaches natural drainage, including top of banks, bottom of banks, thalweg, and grade breaks.
- Riprap perimeter.
- Water surface elevation of the receiving waters. Note time and date. Identify any highwater elevation at the outfall.

Note pipe size and material using point attributes and/or field notes.

5.5.8.5 Detention Ponds

A detention pond is an artificially created basin designed to temporarily store stormwater runoff. A detention pond outlet structure regulates the discharge to a downstream drainage system. Survey the pond using grade breaks and ground shots to define the extents and volume. At the outlet structure, survey the following:

- Invert of structure floor.
- Top of structure.
- Invert and top of all pipes at the structure.
- Invert and top of outlet at ends of the pipes.
- Grate size and dimensions including opening areas.

Use survey points to define the dimensions of any weirs or note the weir dimensions with reference to a survey point. Note structure material using feature codes or field notes.

5.5.8.6 Proposed Outfall

Hydraulic design may identify areas requiring topographic survey where a proposed new outfall is expected. These areas require a topographic survey that conforms with Section 5.5.3.

5.5.8.7 Photos

Take photos and index them by point number at the following features:

- Outfall structures, pipes, and ditches.
- Downstream of outfall pipe.
- Drop inlet grates.
- Drop inlet interiors.
- Curb inlets or slotted drains.
- Detention ponds, infiltration basin.
- Detention basin structures.
- Manhole interiors (remove lid, do not enter).

5.6 Deliverables

MDT standard format files and brief descriptions for engineering surveys submitted by consultants in AutoCAD Civil3D format are as follows:

- XXXXXXXDIMAPZ01.DWG – 3D Autodesk file.
- XXXXXXXDIDTMZ01.XML – LandXML file of surface.
- XXXXXXXDINNEZ01.CSV – CSV with attributes (point ID, northing, easting, elevation, feature code, attributes).
- XXXXXXXDINNEZ01.TXT – ASCII file with all culvert information (point, northing, easting, elevation, type, coating, usage, size, culvert end, end treatment, edge protection, damaged end, condition, comment).
- XXXXXXXDINNEZ02.TXT – ASCII file with all hydraulic information (point, northing, easting, elevation, feature).
- XXXXXXXDIGPAZ01.ZIP – Compressed file of all information and data files for the submittal.
 - Include a photos subfolder with all hydraulic-related photos, indexed by point numbers.
 - Include a field notes and sketches subfolder containing all notes and sketches that pertain to hydraulics and hydrology.

- XXXXXXXDIRMEZ01.TXT – Text (Notepad) file explaining the submitted files and how the survey was performed.

5.6.1 Support Information

MDT requires the delivery of dated and neatly organized original field notes, including critical field measurements, as a PDF file, named logically with the project UPN.

MDT requires the delivery of calibration reports, data collection files, raw files, and office processing files. See [Chapter 3: Equipment](#) for calibration report requirements.

5.6.2 File Size Limitations

File size standards are not provided due to the difficulty in establishing limitations that will not be out of date during the use of this manual. However, it is essential to consider the practicality of the file sizes for the computers and/or devices that will be utilizing them. Keep in mind MDT is a large organization with a constrained budget that may have some users operating older computers.

PHOTO	TYPE	END TREATMENT
	CMP	FETS
	CMP	Square
	CMP or SSPP	Bevel
	CMP	Square
	CMPA	Bevel
	RCP	Square

PHOTO	TYPE	END TREATMENT
	RCP	FETS
	RCPA	Square
	RCPA	FETS
	RCB	Bevel
	RCB Single	RCB Flared
	RCB Double	RCB Sloped

Table 5.3: Pipe Types and End Treatment